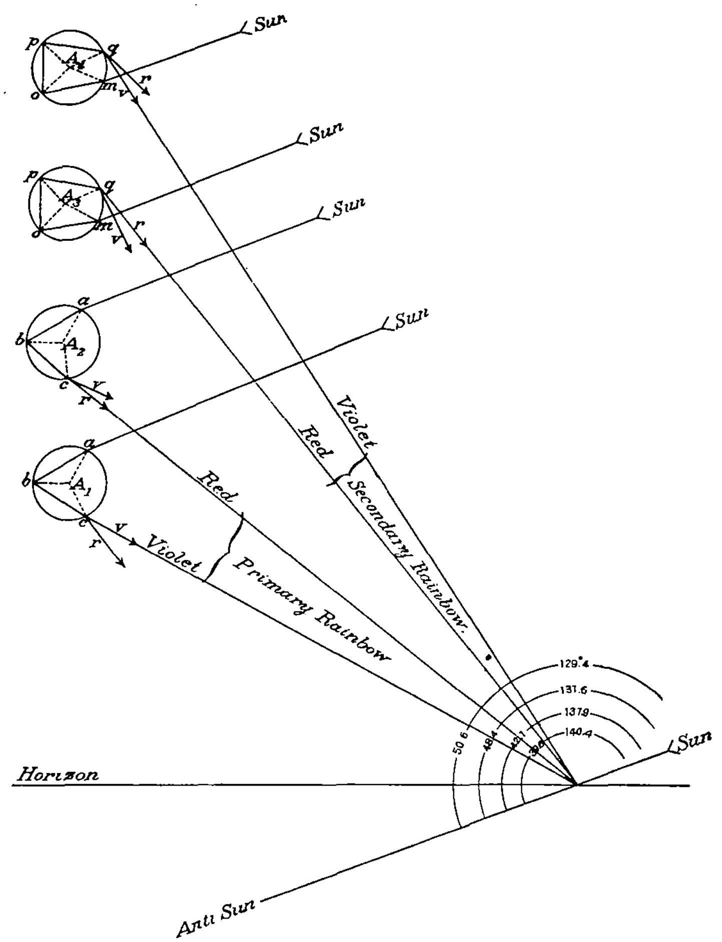

FIG. 1.

drops, like those of a fog or cloud, produce other phenomena called glories and halos. It is the large raindrops that make the finest rainbows, but these large raindrops occur principally in the warmer half of the year and especially in the afternoon thunderstorms. Therefore it is that we see more rainbows during summer afternoons when the sun is nearing the horizon then at any other time. It is not impossible for them to occur at other times, and they can always be seen in the early morning or late afternoon in the falling drops of a fountain or waterfall; sometimes also in the dew-drops on a lawn. Attempts have been made to photograph the rainbow and to a certain extent have been successful, but the colored lights are much fainter than the white light above and below it; one needs a dark background to bring out the rainbow effectively. Moreover, one can not photograph all colors of the spectrum on any one sensitive plate. The plate that will photograph the blue end will not show much of the red, and visa versa, and of course the ordinary photographs do not show the colors, but only black and white. It will merely show a bright arc corresponding to that color band in the rainbow to which the plate is specially sensitive, if indeed the diffuse light from the clouds does not entirely obliterate the photographed image of the colored bows because the latter are not very rich in actinic rays.—*C. A.*

FORMATION AND MOVEMENT OF HURRICANES.

A correspondent writes:

> If I take a flask of saturated air at atmospheric pressure and absorb all the moisture in it by chemical combinations or by condensation, a partial vacuum is produced, and if I then remove the stopper there is an inrushing of air to complete the equilibrium.

On this fact as a basis he builds up the theory that the condensation of moisture in the free air and its deposition as rain relieve the atmosphere of a certain weight and volume, thereby producing an inflow of air from all sides and the resultant phenomena of a whirlwird or hurricane. This is essentially the theory elaborated by H. W. Brandes and summarized in his Beiträge zur Witterungskunde in 1820. Simultaneously with Brandes in Germany, Espy was carrying on his studies in the United States, and in 1826, or soon after, he came upon the idea that the condensation of atmospheric moisture into cloud and rain, while it might relieve the atmosphere of a small percentage of its weight, must on the other hand involve a great quantity of latent heat, thereby expanding the neighboring air, so that we can not properly speak of the formation of a partial vacuum. The air accompanying the condensed moisture expands, has a smaller specific gravity, and will therefore be pushed upward by buoyancy. Its expansion counteracts all tendency to low pressure.

An excellent exposition of this phase of the problem is given by Professor Hann in the Meteorologische Zeitschrift for 1874, a translation of which will be found on pages 393–396 of the Annual Report of the Smithsonian Institution for 1877.

It therefore becomes at once evident that the low pressure at a storm center does not represent the mere loss of the weight of the falling rain, but that the evolution of latent heat produces a buoyancy that itself produces an upward current, whence follows an inflow to supply the place of the ascending air. This inflow may in the rarest of cases be directed exactly toward the center, and Espy maintained that in all cases of small storms on land the observations showed such a direct radial motion inward. On the other hand, Redfield showed that in large storms on the ocean the rotary or circular motion was much more prominent. Both these and numerous European students described the low pressure within the storm area as due to the centrifugal force developed by the rotation around the storm center. Ferrel showed that this was not sufficent, except possibly in the tornadoes and dust whirls, but that in all large storms on land and ocean an additional centrifugal force, which he calls a deflecting force, due to the rotation of the wind with the earth around the earth's axis must also be considered. These combined centrifugal forces increase with the velocity of the wind relative to the earth's surface, and the velocity of the earth's surface about its axis, which latter depends upon the latitude. An excellent exposition of the whole subject was given by Dr. Julius Hann in the Meteorologische Zeitschrift for 1875, a translation of which is published on pages 426–444 of the Annual Report of the Smithsonian Institution for 1877. We quote the following paragraphs from the concluding pages of this report:

> Excess of heat or increased amount of aqueous vapor is the first cause of the ascent of air and its influx from all sides. The inflowing air ascends, condenses its aquous vapor, whereby its ascensional power is further increased, and from this cause the disturbance can continue for some time. For reasons previously given, this process can, in the equatorial regions, give rise at most to tornadoes only, and in fact Reid's chart shows no cyclone traced back to 10° latitude, no typhoon traced beyond 9°. The greater expansion of the air in consequence of higher temperature and greater quantity of vapor must without doubt exert an influence upon the barometric pressure. Notwithstanding this, that theory is untenable which ascribes all barometric variations to the condensation of cyclonic vapor, for according to it the variations of atmospheric pressure would be greatest at the equator. The atmosphere is exceedingly mobile. Every disturbance of equilibrium will be quickly restored by an inflow of air, provided no whirl arises. If, therefore, the earth had no rotation about an axis, there would the nonperiodical barometric variations nowhere be greater than they are at present at the equator. * * *
>
> The progressive motion of cyclones can be explained by the inequality of the centrifugal forces on the polar and equatorial sides of a cyclone. The term of the gradient depending on $2\,n \sin \phi$ is greater on the polar than on the equatorial side, while the other moments remain the same. The cyclone therefore moves toward the direction of the greater diminution of pressure, or toward higher latitudes. It is therefore not necessary to assume that a real transfer takes place from the equator to the pole of the mass of air that forms the cyclone. The deviating force

and the motions are greater on the polar side of the cyclone, and on this side new portions of the atmosphere are continually drawn into the movement, since on this side $n \sin \phi$ is increasing steadily, while on the equatorial side the motion ceases by reason of the frictional resistance and inertia of the air. Thus the center of the cyclone is continually being formed anew during the progress toward higher latitudes. At the same time the cyclones in the region of the trade winds follow the general movement of the atmosphere, in these latitudes from east to west. From the resultants of the two constant forces, the polar tendency of the cyclones and the influence of the prevailing movement of the atmosphere, there result the parabolic paths of the cyclones, or their recurving when they pass from the trade winds into the region of the west winds.

The influence that a prevailing general current of air exerts upon the progress of a whirlwind that has entered into it evidently consists in this, that the masses of air drawn into the whirlwind have to follow two impulses: one, that which is due to the whirl, and the other, that which is due to their original movements. Therefore, in the region of trade winds and on the northwest side of a whirl, the motions are most accelerated, but on the opposite side are most retarded, and thereby the whirl must receive a tendency to progress toward the northwest. I believe that in its principal feature this agrees also with Lommel's theory of the recurving of the paths of cyclones on their leaving the trade wind region.

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It would certainly be of the highest interest to know the distribution of temperature in the trade-wind region during a cyclone, for this would afford an important test of our storm theories. I believe, however, that students will find fewer difficulties in my presentation of the influence of a general atmospheric current upon a cyclone entering therein than in Lommel's. I do not think that everything is explained by this and by Ferrel's "polar tendency," but certainly both views should be taken into consideration.

But the buoyancy due to evolution of latent heat is only a part of the force at work. The moment a haze or cloud is formed in the presence of sunshine, the radiant solar heat is absorbed by it. All the heat that should strike the ground does its work at the upper surface of the cloud. The cloudy particles are evaporated, the outer layer of the cloud is warmed, and the cloud as a whole receives a great addition to its buoyancy. One may easily observe the illuminated side of a cloud rising while the shaded side is often falling. The indraft toward a storm region is thus greatly stimulated, and the storm increases in intensity. The barometer does not fall by virtue of solar heat, but by virtue of the increase in the movements of the air. The heat which first warms the cloud, just as it would otherwise warm the air at the ground, does not generally long remain manifest as heat to the thermometer; it becomes latent and maintains in the air a larger amount of moisture than would otherwise be present. This moist air is less dense than dry air and, therefore, more buoyant. Consequently, the ascending masses of air in the atmosphere may have the same temperature as, or be even colder than, adjacent descending masses of comparatively drier air. Either heat or moisture may suffice to make the air buoyant.

In ancient times, Dove spoke of the storms of the North Temperate Zone as occurring between two great currents of air, the northerly, or polar, and the southerly, or equatorial current, and many writers, rather prematurely, taught that great storms were generated in the region between these currents. To this idea two objections were made, namely, that on the one hand the polar and equatorial currents were too far apart and too feeble to have any such interaction on each other, and generate such violent whirls. On the other hand, if this were the sole cause of the hurricane, the latter would soon die away by reason of the resistances to the motion of the wind, and some regenerating process must be discovered in order to explain the generally steady increase in the intensity of such hurricanes up to the maximum before they begin to die away. After many years of discussion on these points it seems now to be generally admitted that a hurricane may begin in the space between opposing currents from the north and south quite as easily as in a region where buoyant air is rising and cloud and rain being formed, because there is a slight diminution of pressure in the space between such opposing currents sliding past each other, a diminution sufficient to induce a slight indraft and the formation of a gentle whirl. As to the maintaining power, however, it still appears likely that the principal source for this must be found in the condensation of moisture, the evolution of latent heat, and the interception of sunshine by the cloud. But we must add to these the further consideration that if the air to the northward is abnormally cold or dry, or that to the southward abnormally warm and moist, then the centrifugal force of the earth's rotation will drive the northerly air toward the equator, while the lighter air, by its buoyancy, is driven northward. Just as centrifugal force acts in separating cream from milk in the separator used in the dairy, while gravity separates the cream from the milk by a slower process in the old-fashioned dairies, so in the earth's atmosphere the heavy air is drawn to the ground by gravity or driven to the equator by centrifugal force, while the lighter air is pushed upward, or pushed northward, respectively. The general interchange of air between the polar and equatorial regions is due to differences of temperature, moisture, centrifugal force, and gravity, and is known as the general circulation of the atmosphere. We may therefore say that a whirl, when once started, developes into a hurricane under the combined favorable action of three forces; namely, the general circulation of the atmosphere, the absorption of solar heat by its own clouds, and the formation of cloud and rain with evolution of latent heat by its own internal currents and by the moisture of the air drawn into it from without. The relative importance of these three depends upon latitude, and must vary from storm to storm, and from day to day.—*C. A.*

A LEGAL DECISION AS TO DAMAGE BY LIGHTNING AND WIND.

In a periodical published by the University of Dijon we find an interesting decision by the civil tribunal of that city, relative to responsibility for damage done by lightning and wind. A few years ago we published a decision of the United States Circuit Court of Appeals (MONTHLY WEATHER REVIEW for December, 1900, p. 550) to the effect that forecasts of local rain have not yet attained such commanding respect by reason of their accuracy as to justify us in holding shippers guilty of culpable negligence if they do not provide against damage against heavy rains when light local showers are predicted. "The case of local rains is different from that of storms of great violence, whose existence, course, and time of arrival are publicly announced by signals which the master of a vessel is bound to observe."

With regard to the case on trial before the court at Dijon, the record shows that on June 30, 1901, at about 6 p. m., after a day of exceptional thunderstorms, an extremely violent wind occurred, producing great destruction. Besides the destruction due to the wind, many cases were found in which the damage was undoubtedly due to lightning. Public opinion and the local press attributed everything to the passage of a tornado. The work of destruction was accomplished in a few moments, and was followed by a heavy fall of hail over a large area, after which occurred an exceptionally heavy rain. The administration of the docks of Burgogne attributed a certain damage to lightning, and demanded that the repairs should be made by the nine companies in which they were insured; but, on the contrary, the insurance companies maintained that the disaster was equally attributable to the wind, and that, according to their policies, they did not insure in any manner against damage done by "hurricanes or cyclones, tornadoes, or any other meteorological or electrical phenomenon, except thunder and lightning."

In the trial before the judges, the facts of the disaster, the wind, and the lightning, were abundantly established. Then came a large mass of testimony relative to phenomena observed in Europe and America in connection with thunderstorms and tornadoes. Written or printed documents were